TITLE
FLUID TREATMENT DEVICE

FIELD OF THE INVENTION

The present invention relates to an apparatus for treating fluids with ultraviolet ("UV") light, and in particular provides an apparatus that equally distributes UV dose so as to achieve increased treatment effectiveness.

BACKGROUND OF THE INVENTION

The use of UV radiation to kill microorganisms in air or in fluid systems is well known. Often such systems comprise UV reactors that have rows of UV lamps. It is known to offset successive rows so that the fluid passes through the spaces between the lamps in the first row and contacts the lamps in the second row. A patent to Wedekamp, U.S. Patent No. 5,200,156, ("Wedekamp") discloses one such system. The primary concern disclosed in Wedekamp was offsetting the lamps so that the light can pass upstream and downstream unobstructed.

However, the system disclosed in Wedekamp and other traditional UV systems have failed to provide a apparatus that is able to equally distribute UV dose throughout the system, and that is therefore capable of achieving uniformity in dose. The failure of those traditional systems relates to a phenomenon that has been, up until now, ignored. That phenomenon is that the UV lamps that are used to treat fluids emit less UV in the downward direction than in the upward direction. This is particularly relevant with large medium pressure mercury arc lamps. Therefore, in traditional systems wherein the UV light sources are arranged next to one another and sometimes in offset rows, there could be areas in the reactor where the dose is low. This is especially so in the area below the lamps, where, as described above, the lamp output is reduced, thereby contributing to a low dose in this zone and hence a wide dose distribution. Therefore, a traditional system may provide some of the fluid with a low dose of UV and some of the fluid with a high dose. Ideally, UV treatment systems and methods would provide a narrow dose distribution.

It would therefore be desirable to eliminate the undesirable effect of a non-uniform dose distribution. It would further be desirable to increase uniformity in dose distribution by causing more of the fluid to flow into the treatment area.

Another problem in designing UV reactors for treatment of fluids is that in an installed system, the fluid quality and flow rate may vary from one system to another and from moment to moment. Thus, there is a need for modular assemblies that can be incorporated into a reactor in any number to account for such variations.

SUMMARY AND OBJECT OF THE INVENTION

The present invention is a novel fluid treatment device that for the first time takes into account the phenomenon described above wherein UV sources emit less UV light in the downward direction than in the upward direction. The inventive system comprises a housing for receiving a flow of fluid. The invention for the first time uses a modular assembly of UV lamps. The modular assembly comprises at least two UV sources substantially parallel to each other and transverse to said flow. In an embodiment, one of the UV sources is disposed in a plane below all such other lamps and adapted to be run at a power higher than that of all such other lamps. The inventive arrangement is combined with a baffle arrangement wherein the baffles are preferably positioned in such a way to direct the fluid flow into the treatment area.

In this way, the invention achieves its objects. One of the objects of the invention is to provide a UV light arrangement wherein the lower lamp is run at a higher power so as to provide a uniform dose of UV light being emitted across the cross-section of the reactor, thereby achieving a uniform dose distribution.

It is a further object of the present invention to provide an arrangement of baffles that causes the fluid to flow in close proximity to the UV sources, thereby increasing dose effectiveness.

It is still a further object of the invention to provide a geometry for an arrangement of baffles that increases uniformity in dose distribution by causing the fluid to flow into an area uniformly treated by the UV sources by adjusting the dimensions of the lower baffles.

It is still a further object of the current invention to provide the fluid treatment zones in modules that can be incorporated in a reactor in any number sufficient to achieve the required dose. For example, for a given flow if the water quality is low (low percent transmitence for a

UV reactor) more modules can be included to achieve the required treatment dose. In addition, for a given reactor, during operation, if the flow rate through the reactor is low or the water quality is high, not all the modules need be operated thereby reducing the cost of operating the reactor. This high degree of "turndown" in the reactor is attractive both in sizing the reactor for a given application and in operating the reactor to reduce operating cost.

Still further, an object of the present invention is to incorporate assembly modules that are substantially tuned to a corresponding set of lamps and baffles such that they can be run independently of other modules and such that any number and position of modules can be run in combination to achieve the required dose.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is on isometric view of a reactor having the inventive system therein.

Figure 2 is a side view of the reactor.

Figure 3 is a cross sectional view of the reactor.

Figure 4 is a schematic representation of UV distribution in the reactor.

Figure 5 is a schematic representation of the fluid flow in the reactor.

Figure 6 is a graph showing efficiency versus baffle depth.

Figure 7 is showing the relationship between the power of the lowermost UV source and the other UV sources in the according to the present invention.

Figure 8 is a schematic representation how the claimed invention achieves a uniform dose distribution in light the newly-discovered phenomenon disclosed herein.

Figure 9 is a graph showing thermal convection effects above and below UV sources of the present invention.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Figure 1 shows a fluid treatment device according to the present invention. The fluid treatment device comprises a housing **1** that receives a flow of fluid. The direction of the flow is indicated by arrow **A**. The housing comprises a fluid inlet **2** into which the fluid flows and a fluid outlet **3** out of which the treated fluid flows. Disposed between the fluid inlet **2** and the fluid outlet **3** is at least one assembly **4**, preferably a modular assembly, of UV sources **10,20,** and **30**.

In Figure 3, the modular assembly **4** of UV sources **10,20,** and **30** comprises at least two UV sources, and in the preferred embodiment contains three UV sources. The UV sources **10,20,** and **30** in the assembly are preferably medium pressure UV lamps. Each lamp is contained within a quartz sleeve **12,22,** and **32**, which are only depicted in Figure 3 as being in the middle modular assembly, but which are preferably around each lamp. In a preferred embodiment, two lamps or UV sources **10** and **30** are disposed nearer to the inlet **2** (inlet shown in Figure 1) than the third lamp **20**. The UV sources **10** and **30** are spaced apart in the reactor sufficiently far such that the velocity of fluid between them is not high enough to achieve excessive pressure drop in the reactor but sufficiently close such that the UV fluence is not too low to achieve the adequate dose for fluid at the point furthest from the lamps. The third lamp **20** is placed at a position downstream of the first two lamps, **10** and **30**, usually at a distance from the first two lamps, **10** and **30**, of between 0.25 and 2 times the lamp spacing between the first two lamps **10** and **30**. This positioning of the third lamp **20** downstream from the first two, **10** and **30,** permits the fluid to flow in an unimpeded fashion between the first two, **10** and **30**, but not so far as to allow the fluid that passes furthest from the lamps to wander far away from the third lamp **20**, which would cause the fluid to not receive a sufficient dose. Therefore, the angle from the vertical line between the first two, **10** and **30,** lamps to the third lamp **20** can be roughly from 45 degrees to 76 degrees. These angles and distances at which the lamps and respective sleeves are disposed to one another is the lamp geometry.

Each modular assembly has associated with it at least one baffle, preferably a set of baffles, and more preferably a set of two baffles. The preferred arrangement of baffles, **40** and **50**, is depicted in Figures 3 and 5. The lamp geometry and baffles act as a baffling mechanism to direct the flow of fluid so as to increases uniformity in dose distribution by causing the fluid to flow into an area where it will receive uniform treatment. This is achieved because the geometry and dimension of the baffles are adapted to direct a sufficient amount of fluid between the lamps **10** and **30** and to prevent too much of the water to from passing above lamp **10** or below lamp **30.** Typically, the lamp disposed nearest to the top of the housing **10** shines half its UV light down into the middle zone between lamps **10** and **30.** The bottom lamp shines half its light up into the middle zone. And the third lamp **20** shines all its light into this middle zone. Thus, as depicted in Figure 4, two thirds of the UV light is concentrated in this middle zone. Because of this phenomenon, the baffles are arranged such that two thirds of the fluid is directed into this

middle zone. Since the flow of fluid is roughly proportional to the area afforded for it to flow, the baffle is sized such that the area for flow is roughly one sixth above the top lamp **10**, two thirds between the front lamps **10** and **30** and one sixth below the bottom lamps **30** as shown in Figure 5.

In a UV reactor baffle height is adjusted from this rough dimension as a result of computer modeling or testing the reactor with different baffle heights and thereby finding an optimum baffle height that produces the best dose distribution while not producing too high a velocity and hence pressure drop through the reactor. In addition the baffles can be positioned upstream of the front lamps and angled towards the lamps. The angling of the baffles helps reduce pressure drop through the reactor while not affecting dose distribution significantly. Pointing the baffle directly at the lamp helps reduce "shadowing" in areas in the reactor behind the baffle. While the baffles in Figures 3 and 5 show the baffle at a 45 degree angle and point directly at the lamp, this is not necessary. Baffle angles from 90 degrees to 20 degrees provide similar dose distribution, but provide increasingly lower pressure drop. 45 degrees is shown as a preferred embodiment of the current invention as providing reduced pressure drop without taking up excessive space longitudinally in the reactor.

The baffles can be at any angle to the wall with a smaller angle resulting in lower pressure drop and a larger angle resulting in a shorter length of pipe needed to accommodate the baffle. The baffles are generally disposed upstream of the first pair of lamps to ensure all the water is diverted into the high irradiation zone surrounding the lamp.

The extent to which the baffle penetrates into the reactor and diverts flow from the regions above and below the lamps to the zone between the lamps was determined by computerized modeling of the reactor using a combination of Computational Fluid Dynamics (CFD) and Irradiance Distribution Modeling. The efficiency of a configuration is defined as the ratio of the dose a surrogate organism is subjected to the theorectial dose that would be achieved in a perfectly mixed reactor. This is shown in Figure 6 together with the pressure drop across the reactor. As would be expected the pressure drop increases with increasing baffle depth. However the efficiency achieves a maximum and reduces as more water is forced between the lamps, wasting some of the UV light above and below the lamps.

At least one of the lamps **30** and its respective sleeve, is disposed in a plane below that of the other lamps **10** and **20** in the assembly. This lamp **30** is run at higher power than the other

lamps. This is to address the phenomenon of UV lamps emitting less UV in the downward direction than in the upward direction. By running the lower lamp **30** at a higher power, the fluid at the lower end of the housing will receive the same dose as the fluid that is closer to the lamps, thus providing a uniform distribution of dose. The ratio of power between the lower lamp and the other lamps in each bank varies depending on the lamp length, lamp diameter and lamp power. For long and powerful lamps, the ratio can be up to 1.3 when the lamp is running at full power and up to 2.0 when the lamp is running at reduced power (maximum turndown).

This relationship between the power of the bottom lamp and the other lamps is shown in Figure 7 in an operating system where the lower lamps must be powered at approximately 5kW higher than the upper lamp to get the same UV irradiance of the desired wave length. Field data from a test reactor showing the relationship between UV Irradiance and Lamp Power. Lamps 1-1, 2-1, 3-1, 1-3, 2-3 and 3-3 are viewed with the UV Sensor from above. Lamps 1-2, 2-2 and 3-2 are viewed from below at the same distance from the lamp. This shows that approximately 5 kW more power is needed to achieve the same irradiance below the lamp as above the lamp.

This power premium, as high as 20% of full lamp power in the example above, varies depending on the lamp power, lamp dimensions and lamp environment. In lower powered and correspondingly shorter lamps, it is much less pronounced.

To compensate for this phenomenon and achieve an even dose distribution in a reactor the bottom lamp can be run at higher power than the upper lamps. This is illustrated in the Figure 8 where, for example, operating the upper two lamps at 20 kW produces an irradiance of 100 above and 80 below. Operating the bottom lamp at 25 kW produces an Irradiance of 125 above and 100 below. The most vulnerable parts of the reactor are the points furthest from the lamps where the irradiance is lowest but between the baffles where the flow velocity is high. In the example the combined irradiance is 100 at the top baffle, 90 between the top lamp and middle lamp, 102.5 between the middle lamp and bottom lamp and 100 at the bottom baffle. Thus, the irradiance distribution has been evened out by running the lower lamp at higher power thus improving the overall efficiency of the reactor. This can be simply achieved by running the each of the lamps to achieve the same UV setpoint value (100 in this case) and applying the UV irradiance sensor such that upper UV sources are viewed from above and the lowermost from below.

It has also been surprisingly found that because of thermal convection effects surrounding and within the lamp, the plasma arc tends to rise up in the lamp. This leaves an area below the lamp where mercury vapor is present but no plasma exists and hence, no emission of UV light. This mercury vapor will absorb UV, in particular in the wavelength band around 254 nm were mercury absorption is the strongest. The dramatic drop in the desired UV measured by a spectroradiometer between 252 nm and 260 nm is shown in Figure 9, which involves Spectral Irradiance measured above and below a lamp and shows the reduction in the output in the band around 254 nm.

This effect is also dependent on the dimensions and other design parameters of the lamp. A longer lamp or a lamp with a larger diameter will show a more accentuated drop in output in this region as illustrated. A shorter lamp or thinner lamp will reduce this effect. It is therefore important to choose a lamp for service in the reactors described here to minimize this effect. For higher-powered lamps, however, it is not possible to eliminate the effect altogether.

An alternative method of dealing with the lower irradiance in the bottom of the reactor due to the lower output below the lamps than above, is to increase the length or alter the positioning of the lower baffle **50** (shown in Figures 3 and 5) in order to reduce the flow of fluid into this zone of lower irradiance. Another alternative to running the bottom lamp at a higher power is to move the lower lamp closer to the bottom of the reactor at a distance from other lamps such that a uniform irradiance is achieved.

While presently preferred embodiments of the invention have been shown and described, the invention may be otherwise within the scope of the appended claims.